Bell Ringer: Impulse and Momentum – ID: 13605

Based on an activity by Irina Lyublinskaya

Time required
15 minutes

Topic: Momentum and Collisions

- *Derive the impulse-momentum theorem, $F\Delta t = m\Delta v$, to solve problems involving force, time, mass, and velocity.*

Activity Overview

In this activity, students explore the relationships between momentum, force, and impulse for the linear collision of a ball with an unmovable wall. Based on these explorations, students derive the impulse-momentum theorem and then apply this theorem to solve problems.

Materials

To complete this activity, each student will require the following:

- *TI-Nspire™ technology*
- *pen or pencil*
- *blank sheet of paper*

TI-Nspire Applications

Graphs & Geometry, Notes

Teacher Preparation

Before carrying out this activity, review with students how to calculate the total momentum in a system. Also, review resolving vectors into their components.

- *The screenshots on pages 2–4 demonstrate expected student results. Refer to the screenshots on page 5 for a preview of the student TI-Nspire document (.tns file). The solution .tns file contains sample responses to the questions posed in the student .tns file.*
- ***To download the student .tns file and solution .tns file, go to education.ti.com/exchange and enter "13605" in the search box.***
- *This activity is related to activity 9900: Impulse-Momentum Theorem. If you wish, you may extend this bell-ringer activity with the longer activity. You can download the files for activity 9900 at education.ti.com/exchange.*

Classroom Management

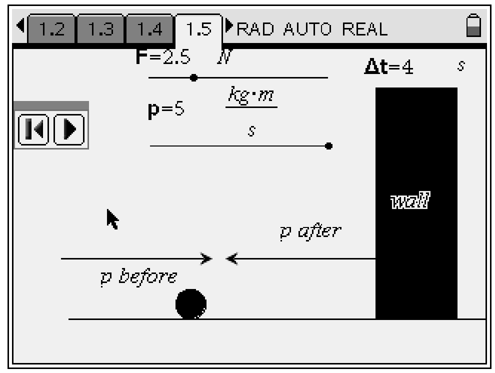
- *This activity is designed to be **teacher-led**, with students following along on their handhelds. You may use the following pages to present the material to the class and encourage discussion. Note that the majority of the ideas and concepts are presented only in **this** document, so you should make sure to cover all the material necessary for students to comprehend the concepts.*
- *If you wish, you may modify this document for use as a student instruction sheet. You may also wish to use an overhead projector and TI-Nspire computer software to demonstrate the use of the TI-Nspire to students.*
- *If students do not have sufficient time to complete the main questions, they may also be completed as homework.*
- *In some cases, these instructions are specific to those students using TI-Nspire handheld devices, but the activity can easily be done using TI-Nspire computer software.*

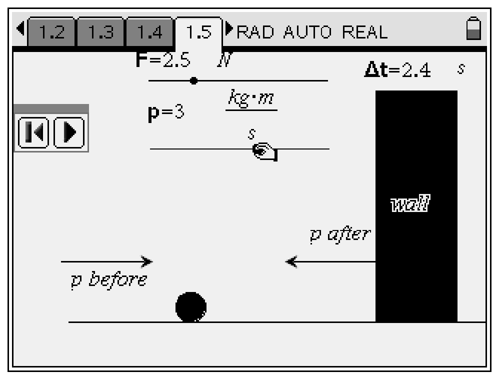
The following question will guide student exploration during this activity:

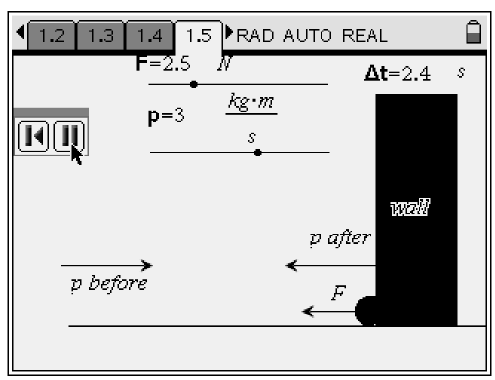
- What is the relationship between the impulse of a force acting on an object and the object's change in momentum?

The purpose of this activity is to allow students to explore the impulse-momentum theorem in the special case of the linear collision of a ball with a wall. Students observe changes in momentum, the time of the interaction, and the force the wall applies to the ball in order to develop an understanding of impulse and its effect on the momentum of the ball.

Step 1: Students should open the file **PhysBR_week18_impulsemomentum.tns**, read the first four pages, and then move to page 1.5. Page 1.5 shows an animation of an elastic collision between a ball and a wall. Students can use the animation control buttons to simulate the ball's collision with the wall, and they can observe how the wall's force acting on the ball affects the ball's motion. It is important here for students to understand that the force from the wall is exerted on the ball only when the ball is actually touching the wall (which is why the arrow for the force **F** appears only when the ball hits the wall). The students should use the sliders to vary the magnitudes of the wall's force (**F**) and the ball's momentum (**p**) and observe the changes in initial and final momentum and time of interaction. (To use the sliders, students should use the NavPad to move the cursor to the point on the line segment located below each variable. They can press and hold to select the point, and then use the NavPad to drag it to change the values.) The momentum values range from 0.08 kg·m/s to 5 kg·m/s. The range of force values is from 0.17 N to 10 N.







Step 2: After students have explored the animation, they should answer questions 1–4.

Q1. How long is the ball in contact with the wall when the force on the object is 5 N and the momentum of the ball is 5 kg·m/s? How long is the ball in contact with the wall when the momentum is half of its original value? How long is the ball in contact with the wall if the force is half of its original value?

A. *From observation of the animation, the ball is in contact with the wall for 2 s in the initial case. When the momentum is reduced by half, the time is reduced to 1 s. When the force is reduced by half, the time increases to 4 s.*

Q2. What is the change in momentum, Δ*p,* of the ball, in terms of its initial momentum, *pbefore?* (Hint: Δ*p* is a vector quantity. Momentum is conserved in an elastic collision.)

A. *The change in momentum is given by* $\Delta p = \left|\overrightarrow{p_{after}} - \overrightarrow{p_{before}}\right|$. *Because momentum is conserved in an elastic collision and the wall's momentum is zero after the collision, the ball's momentum must have the same magnitude before and after the collision. In other words,* $\overrightarrow{p_{after}} = -\overrightarrow{p_{before}}$ *. Therefore,* $\Delta p = \left|\overrightarrow{p_{after}} - \overrightarrow{p_{before}}\right| = \left|-\overrightarrow{p_{before}} - \overrightarrow{p_{before}}\right| = 2p_{before}$ *.*

Q3. What did you observe about the time of interaction between the ball and the wall, the force the wall exerts on the ball, and the change in momentum of the ball?

A. *The force acts upon the ball only when it is in direct contact with the wall. When the magnitude of momentum increases, the time of interaction increases. When force increases, the time of interaction decreases. Encourage students to discuss their observations. Note: The time of interaction between the ball and the wall is calculated using the impulse-momentum theorem,* $\Delta t = \frac{\Delta p}{F}$*, where* $\Delta p = \left|\overrightarrow{p_{after}} - \overrightarrow{p_{before}}\right|$ *. This formula is hidden, and only the numerical value of time is shown on the page.*

Q4. a. Use Newton's second law, $F = ma$, and the definition of acceleration, $a = \frac{\Delta v}{\Delta t}$, to find the relationship between force (F), time of application of the force (Δt), and change in momentum (Δp). (This relationship is known as the impulse-momentum theorem.)
b. Confirm that this relationship works to calculate the values of **F**, **p**, and **Δt** in question 1.

A. *a.* $F = ma = m\frac{\Delta v}{\Delta t} = \frac{\Delta(mv)}{\Delta t} = \frac{\Delta p}{\Delta t}$, *thus* $F\Delta t = \Delta p$

b. The change in momentum of the object in the simulation is 2p. *Plugging in the values yields the following:*

$$(5\ N)(\Delta t) = 2\left(5\ \frac{kg \bullet m}{s}\right)$$

$$\Delta t = \frac{10\ \frac{kg \bullet m}{s}}{5\ \frac{kg \bullet m}{s^2}}$$

$$\Delta t = 2\ s$$

$$(5\ N)(\Delta t) = 2\left(2.5\ \frac{kg \bullet m}{s}\right)$$

$$\Delta t = \frac{5\ \frac{kg \bullet m}{s}}{5\ \frac{kg \bullet m}{s^2}}$$

$$\Delta t = 1\ s$$

$$(2.5\ N)(\Delta t) = 2\left(5\ \frac{kg \bullet m}{s}\right)$$

$$\Delta t = \frac{10\ \frac{kg \bullet m}{s}}{2.5\ \frac{kg \bullet m}{s^2}}$$

$$\Delta t = 4\ s$$

Suggestions for Extension Activities: Have students consider the derived Impulse-Momentum equation to explain the various phenomena in sports. For example, why is it important for a golfer to “follow through” on the swing? Or, why is it important for a gymnast to bend her legs when she lands a jump?

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(Student)TI-Nspire File: *PhysBR_week18_impulsemomentum.tns*

1.1

IMPULSE AND MOMENTUM

Physics

Momentum and Collisions

1.2

The momentum, *p*, of an object is defined as a vector *p* = *mv*, where *m* is the mass of the object and *v* is its velocity. When an unbalanced force *F* acts on the object, the object's velocity will change, so its momentum will also change.

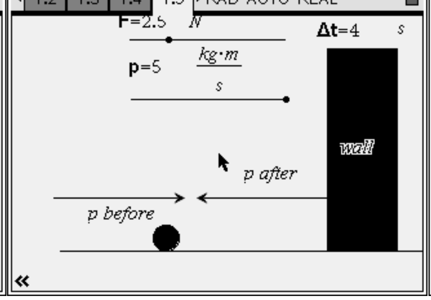
1.3

The amount an object's momentum changes when a force acts on it depends on the magnitude of the force and the time over which the force acts. In other words, it depends on the impulse that acts on it. The impulse produced by a force *F* is defined as $F\Delta t$, where Δt is the amount of time the force is acting on the object.

1.4

The next page shows a simulation of an elastic collision of a ball with a wall. Use the animation control buttons to control the motion of the ball. You can change the momentum of the ball and the magnitude of the force using the sliders. Observe how time of collision, force, and momentum are related to each other.

1.5



1.6

1. How long is the ball in contact with the wall when the force on the object is 5 N and the momentum of the ball is 5 kg·m/s? How long is the ball in contact with the wall when the momentum is half of its original value? How long is the ball in contact with the wall if the force is half of its original value?

1.7

2. What is the change in momentum, Δp, of the ball, in terms of its initial momentum *pbefore*? (Hint: Δp is a vector quantity. Momentum is conserved in an elastic collision.)

1.8

3. What did you observe about the time of interaction between the ball and the wall, the force the wall exerts on the ball, and the change in momentum of the ball?

1.9

4. a. Use Newton's second law, *F* = *ma*, and the definition of acceleration $a=\frac{\Delta v}{\Delta t}$, to find the relationship between force (*F*), time of application of the force (Δt), and change in momentum (Δp). (This relationship is known as the impulse–momentum theorem.)

b. Confirm that this relationship works to calculate the values of *F*, *p*, and Δt in